

Enhance Indoor Environment in Buildings and Its Effect on Improving Occupant's Health

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Abstract—Recently, the world main problem is a global warming and climate change affecting both outdoor and indoor environments, especially the air quality (AQ) as a result of vast migration of people from rural areas to urban areas. Therefore, cities became more crowded and denser from an irregular population increase, along with increasing urbanization caused many problems for the environment such as increasing the land prices, changes in life style, and the new buildings are not adapted to the climate producing uncomfortable and unhealthy indoor building conditions. As interior environments are the places that create the most intimate relationship with the user. Consequently, the indoor environment quality (IEQ) for buildings became uncomfortable and unhealthy for its occupants. The symptoms commonly associated with poor indoor environment such as itchy, headache, fatigue, and respiratory complaints such as cough and congestion, etc. The symptoms tend to improve over time or even disappear when people are away from the building. Therefore, designing a healthy indoor environment to fulfill human needs is the main concern for architects and interior designer. However, this research explores how occupant expectations and environmental attitudes may influence occupant health and satisfaction within the context of the indoor environment. In doing so, it reviews and contributes to the methods and tools used to evaluate only the indoor environment quality (IEQ) components of building performance. Its main aim is to review the literature on indoor human comfort. This is followed by a review of previous papers published related to human comfort. Finally, this paper will provide possible approaches in design level of healthy buildings.

Keywords—Sustainable building, indoor environment quality (IEQ), occupant's health, active system, sick building syndrome (SBS).

I. INTRODUCTION

THE increase demands on different type of buildings such as residential, commercial, offices, educational buildings as a result of increasing population rate and urbanization make buildings responsible for more than 40 % of global energy used (Fig. 1) [1]. In addition, scientific evidence indicates that human health and well-being is influenced by indoor environment as a result of exposure to different environmental contaminants through a succession of daily activities. As people spend approximately 93% of their time in indoor environments (residences, offices, schools, shopping malls, etc.), hence, the indoor building environment plays an influential role on human health [2] Therefore, in recent years, there is increase awareness about the indoor environment and its effect on our health. The indoor air quality (IAQ)

associated with a range of health hazards as it pollutes more than outdoor [3]. A high percentage of diseases among children and elderly people in the world are as a result of polluted air in the indoor environment [4]. Although indoor air quality (IAQ) is an important determinant of indoor healthy environment, other factors contribute to healthy indoor environments include lighting, temperature, noise, ventilation, and security. Factors affect indoor air pollution are building materials, furniture, and indoor humidity, temperature, ventilation rates, and maintenance activities (Fig. 2) [5]. Consequently, the architecture, engineering and construction industries have developed several policies and practices to improve the health and maintain the comfort. Accordingly, several organizations in the whole world emerged, such as LEED, BREEAM, CASBEE; GREEN STAR (NABERS) their main aim is to improve occupant health and well-being through design guidelines (Fig. 3). Therefore, countries should create their own building assessment system to adapt to their climate, materials, and environment [7]. This paper aims to illustrate the importance of applying sustainable and green building design on occupant's health and comfort; it will also clarify the economic and environmental benefits from its use, and in order to reduce the negative impacts on the built environment.

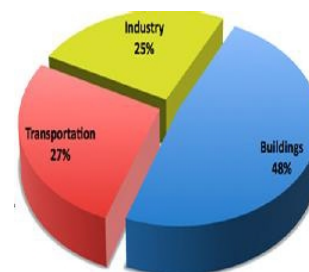


Fig. 1 The Percentage of Energy Used in Buildings [2]

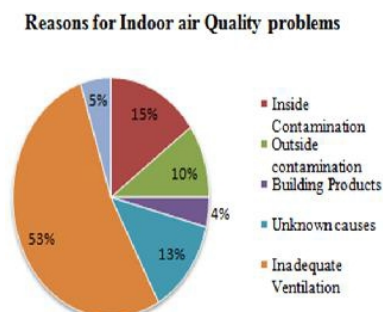


Fig. 2 Indoor Air Quality [3]

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Fig. 3 International Certification Systems [6]

II. RESEARCH AIM AND OBJECTIVES

The aim of this research is to present an overview of the connection between the indoor environment and occupant's health and well-being. In addition, it will show that a good design and construction practices will minimize the indoor hazards and provide a healthier living for its occupants.

III. RESEARCH PROBLEM

As people became more aware about the effects of poor indoor environment on occupants' health, the main problem of this paper is how to measure the effects of the indoor environment and how sustainable design can help improve the indoor environment.

IV. RESEARCH METHODS

The descriptive qualitative method will be used to gain an accurate and detailed knowledge depending on relevant papers. In addition, this research will evaluate different approaches in terms of their impact on the indoor and outdoor environment. Also, present guidelines for designers, contractors and owners to turn buildings to become sustainable.

V. LITERATURE REVIEW

The literature shows an increasing state of awareness concerning indoor air quality. In fact, minimizing the effects of indoor pollutants is a priority in building design, since a high percentage of peoples' time in indoor. The climate changes as a result of increasing greenhouse gas emissions resulted from increasing in building construction which is the main sector in energy consumption; therefore, governments should encourage the building sector to move towards sustainability and an implementation of green specifications [8].

Building performance and its effect on occupant's health and comfort with respect to sustainable design got more attention in the last decade. The government's main concern around the world seeks to improve building performance to ensure reducing building's hazards to health and well-being. Several studies investigated the factors that affect indoor occupants' health, satisfaction and consequently their performance [9], [16]. Health will be improved significantly by improving IEQ, he added improvements in lighting and thermal conditions increase productivity [10], [17]. As a result, LEED organizes these different IEQ (Fig. 4). These studies indicate that IEQ affects health and productivity. Therefore, architects and designers have to be aware about IEQ in their design to minimize health hazards.

A. Sustainable Buildings

Sustainable buildings aim to meet human needs while preserving the environment [7]. Thus, sustainability should minimize environmental negative impacts, conserve natural sources, enhance and protect the nature environment, decrease global warming, heat island effects, pollutions and ozone depletion, while providing a comfortable, healthy and productive environment for its occupants (Fig. 5). Nowadays, recent interest about buildings in general is creating more sustainable and healthy buildings [11], [18]. The need for buildings to consume less natural resources, contribute a smaller carbon emission, and provide better and healthier indoor environments. The resulting changes in the approach to architectural design have a number of consequences which should be considered. The most significant aspect to consider regards the use of natural lighting as approximately 25% of energy consumption in buildings on artificial lighting; in addition, artificial lighting is also a source of heat in indoor spaces. Using natural light needs to change in the plan layout from deep floor plans to more strategically oriented buildings with narrow floor plan and glazing strategically allowing for day lighting of placing openings on the north side of the

building to minimize both the potential for glare and direct solar radiation [11].

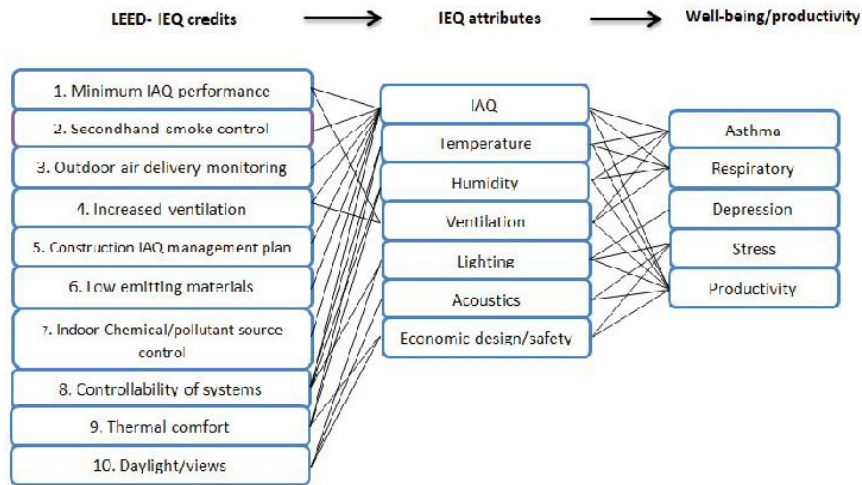


Fig. 4 LEED - IEQ occupant well-being and productivity structure (Source: [16, p. 753])

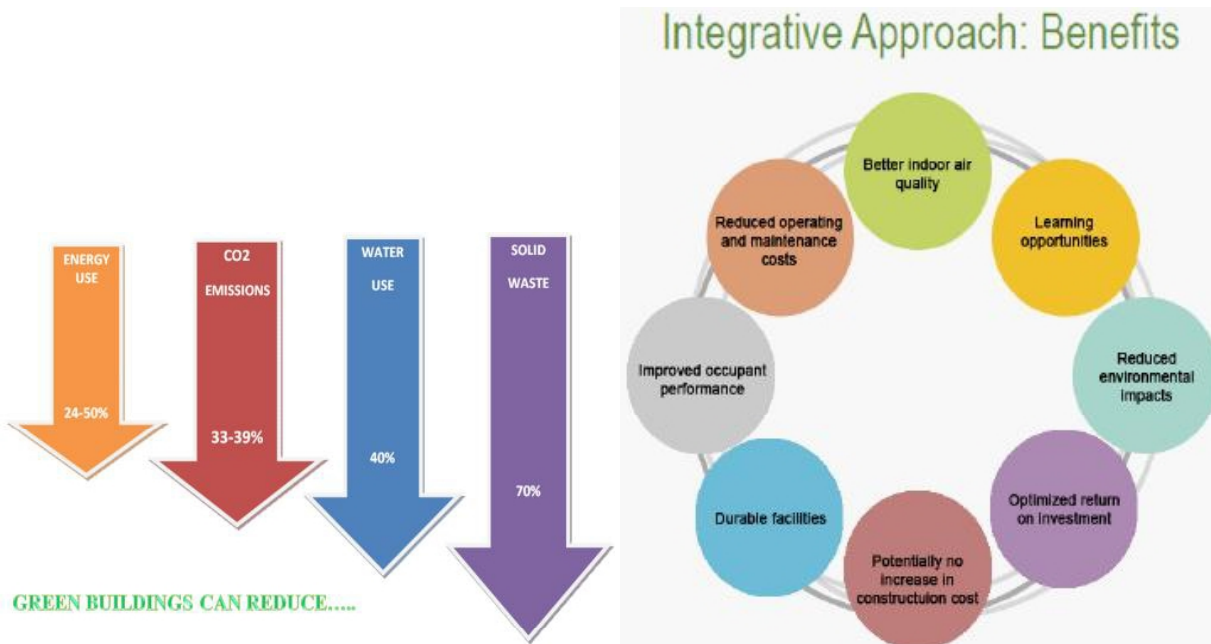


Fig. 5 Benefits of Sustainable building design (Source: [17, p. 100, 105])

B. Pollutant Source Identification

There are so many sources of contaminants contribute in increasing health hazards in buildings. The knowledge of these

sources contributes in putting a proper criteria and guidelines to mitigate their effects. These can be as Fig. 6.



Lead paint for walls & windows, radon in basement and moisture cause health hazards



Carbon Monoxide from kitchen



Mold in Bathrooms & Kitchens



Tobacco smoking



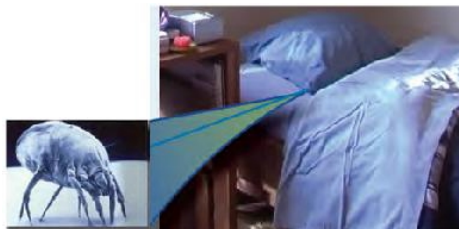
Prevent tripping and falling using escape ladder



Pet's dander



Asthma



Dust mites



Cracks seal to avoid standing water and pests

Fig. 6 Sources of Indoor Contaminants

1. Materials and Inhabitant's Activities

The quality of indoor air is infected by the indoor materials used; therefore, occupant's health is influenced by the materials used. The materials used in buildings and furniture are main sources of indoor volatile organic compounds (VOCs) [12]. On the other hand, some of the indoor pollutants results from inhabitants' activities and can be very harmful. Among these pollutants are: cleaning products, pets, tobacco smoking, etc.

2. Electricity, Heating and Cooling

The indoor environment in general and the indoor air in particular are infected by heating and cooling system as they depend mostly on gas, which pollute the environment when consumed.

3. HVAC Systems

As HVAC is depending on its work on the air taken from outdoor environment, which is polluted from vehicles, parking lot, factories, garbage, producing a poor indoor air quality include carbon monoxide and bacteria. In addition, HVAC noise causes discomfort and headache [13].

TABLE I
INDOOR AIR POLLUTION

Pollutant	Source	Health Effects	Steps to Reduce
1 Radon	Earth, Rock, building materials	Lung cancer	Seal cracks in floor
2 Tobacco smoke	Cigarette, pipe, cigar smoke	Eye, nose, throat irritation, headache	Stop smoking
3 Biological	Wet walls, ceiling, carpet	Eye, nose, throat irritation, fever, asthma	Vents kitchens and bathrooms, clean and dry wet carpet.
4 Carbon Monoxide	Un-vented kerosene and gas heaters, furnaces	Fatigue, impaired vision, headaches, nausea	Ventilate over stove
5 Nitrogen Dioxide	Kerosene heaters, tobacco smoke	Eye, nose, throat irritation, impaired lung function	Ventilate over stove
6 Organic gases	Paints, stains, and strippers	Headaches, dizziness to liver and kidneys	Ventilate area
7 Formaldehyde	Plywood, furniture, particle board	Eye, nose, throat irritation, wheezing, coughing, fatigue, skin rash	Increase ventilation
8 Respirable particles	Fireplaces, wood stoves, kerosene heaters, tobacco smoke	Eye, nose, throat irritation, lung cancer	Vent furnaces

Source: Modified by the Author from [18 p: 40]

VI. DESIGN CONCEPT FOR HEALTHY INDOOR ENVIRONMENT

There are many possibilities for achieving healthy and comfortable indoor environment; these can be summarized as follows:

A. Site Planning

A proper building sitting help to maximize natural resources such as light, heat, ventilation, plants, shade, and maximize the use of natural resources on the site. For example, using

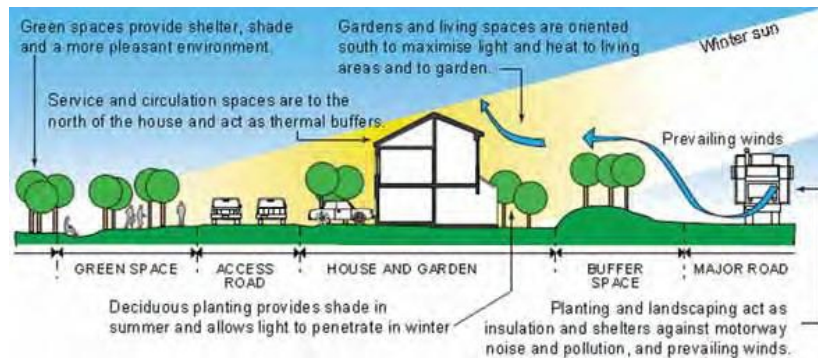


Fig. 7 Using landscape elements for decreasing urban pollutions (source: [19, p. 30])

B. Controlling Solar Gain

Controlling solar gain in buildings by planting shade trees in front of west and south elevations of the buildings are a very effective way to protect buildings from unwanted solar gain and then reduce cooling loads, energy consumption, production of pollutions, noise and other negative impacts (Fig. 8).

deciduous and evergreen plants have a big role in modifying the microclimate in the site. Site planning includes the followings:

1. Urban Solar Radiation

The aim of solar responsive design is to maximize the access of solar radiation to building's indoor spaces in winter and protecting buildings from unwanted solar radiation in summer with enhancing the usages of nature day lighting and ventilating indoor buildings. This design can be achieved by good urban planning, orienting, designing of buildings, choosing suitable building materials and good using of vegetations.

2. Wind Control

Tall buildings which are separated by open spaces can create a pressure difference which creates local ventilation that continues flowing to building's indoor spaces, while landscape vegetation block and control the wind and give shade to exterior walls and therefore reduce indoor heat gain.

3. Air Quality

Vegetation plays a vital role in improving the air quality. In addition, vegetation can block dust and odors from entering indoor buildings (Fig. 7).

4. Landscape

Landscape has more benefits by creating more green spaces with more trees and greener views and other benefits such as:

- Filtering outdoor air and reducing dust.
- Reducing air pollutions, noise and other negative impacts.
- Enhancing local temperature.
- Reducing unwanted wind speed.
- Reducing unwanted solar gain.

C. Landscape and Natural Ventilation

Enhancing natural ventilation and cooling by influencing wind flowing to reduce mechanical HVAC systems, then reducing the consumption of energy and enhancing the quality of the indoor environment is one of the required processes to achieve sustainability in buildings, this is require designing landscape elements to controlling the wind direction (Fig. 9).

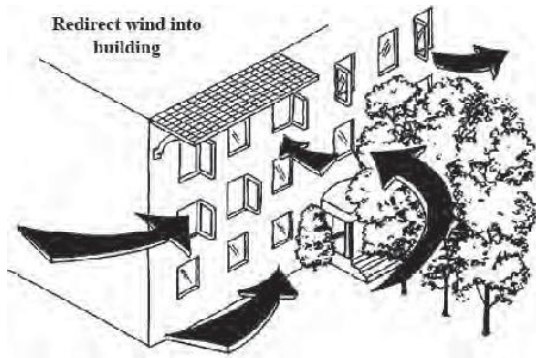


Fig. 8 Using shade trees to conserving buildings from unwanted solar gain [19, p. 42]

D. Roof Garden Systems

The roof garden is very important in controlling indoor temperature, conserving flat roofs from unwanted direct solar gain, reducing pressure on mechanical HVAC systems and enhancing outdoor environment quality.

E. Indoor Landscape

Indoor plants influenced the wellbeing of building occupants as plants enhance the indoor environment and air quality [14], [19]. Plants have the following benefits: reducing carbon dioxide, reducing airborne dust, and keeping air temperatures down.

F. Insulation

The two critical elements in buildings are windows and walls as they can facilitate the intrusion of outdoor polluted air, dust, and heat. Therefore, protecting an indoor environment from polluted outdoor environment will help reduce heat gain, minimizing dependencies on HVAC as a result reducing mechanical noise and creating healthier and comfortable environment.

G. Natural Ventilation

Mechanical ventilation systems are using big amount of energy and considered one of the noisiest and air pollutions sources indoor buildings. Natural ventilation can easily solve those problems by good designing of building by improving the natural ventilation to flow in building's interior spaces to achieve many benefits such as: improving indoor air quality and replacing indoor air which contain CO₂ by new fresh air with O₂, removing moisture, smells and indoor air pollutions [6]. Therefore, suitable orientation of buildings, good designing of building architecture form and articulated walls to make a pressure difference between outdoor and indoor to dragging air flowing into building's interior spaces.

H. Indoor Acoustical Comfort

A good planning of building control both indoor and outdoor noise from its source or decreasing its effects in indoor spaces [20].

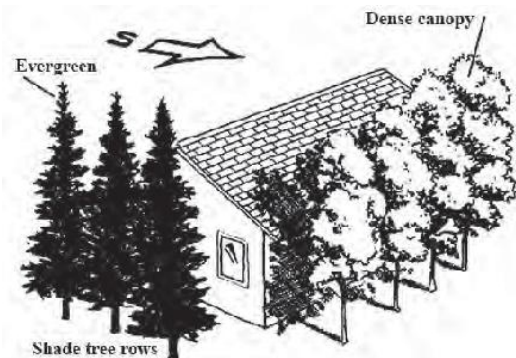


Fig. 9 Using landscape to controlling the direction and speed of wind [19, p. 43]

I. Materials Conservation

Construction of any building needs building materials, these building materials should be green materials which have low consumption of energy, low or no chemical emissions or toxic compounds in the environment.

J. Natural Day Lighting

Natural day lighting has an impact on occupant's health, comfort, performance and satisfaction; it is also influenced buildings energy usages. The design of buildings which depend on natural day lighting concept is very complex because it should be integrated with: designing of artificial lighting, building architecture form, orientation, and elevation details, many benefits of natural day lighting such as reducing pollutions which is resulted from artificial lighting and enhancing the visual quality of building's indoor spaces by connecting to outdoor views [21], [22]. Buildings architecture form has major impacts on improving natural day lighting usages in building's indoor spaces by considering it in designing roofs and openings elements such as: windows, skylights, roofs and others to improve natural day lighting usages.

VII. CONCLUSIONS

Green building design should have more attention from architects, designers and policy makers. In addition, the community must become more aware of the benefits of green and sustainable design which reflects on improving occupant's health and wellbeing. Besides, encouraging universities and schools to include sustainable and green design in their curriculum will have a generation of architects and designers aware of the benefits of green design. Different campaigns for communities to enhance their awareness of green buildings and its benefits and to adapt their behavior with green design.

Finally, for indoor environment to perform effectively and healthy for its occupants, a shift is required from occupants to play a more active role to adjust their behavior inside their buildings as inhabitants' activities can be very harmful [15]. It is essential to increase peoples' awareness for sustainable building design and building uses.

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